

Effect of ultrasound treatments on bacterial quality of table eggs during refrigerator storage

Haider Y. Abbas, Hussein H. Tariq and Shahrazad M.J. Al-Shadeedi*
College of Veterinary Medicine, University of Baghdad, Iraq.

***Correspondence:**

shahrazad@mracpc.uobaghdad.edu.iq

Received: February 13th 2026

Accepted: March 20th 2026

Published: April 26th 2026

DOI:

<https://doi.org/10.63799/AJOS/15.1.1>



ABSTRACT

Ultrasound has used as a green technology to preserving food and food products, it destroys pathogenic microorganisms without side effect and preserving the organoleptic properties. So, an experiment was conducted to compare three periods of ultrasound treatment of table eggs, 1, 2, and 3 minutes, using a conventional ultrasound device, in terms of bacterial count during 0, 1, 2, 4, and 8 weeks of refrigerated storage. A total of 240 fresh table eggs (red-shell eggs) were collected randomly from a flock of 20,000 Lohmann laying hens at Al-Amir Commercial Project Farm in Al-Musayyab city, Iraq. The eggs were divided into 4 treatments (60 eggs/treatment); T1: control, T2: ultrasound for 1 min. T3: ultrasound for 2 min. and T4: ultrasound for 3 min. The results of total bacterial count and total coliform count at Zero time on the shell surface of the T2 and T4 decreased immediately to less than 100 cfu/egg and were 37 X 10¹ and 33 X 10¹ cfu/egg of T2 compared with 43 X 10² and 38 X 10² cfu/egg of T1. As the storage period increased to 2, 4, and 8 weeks in the refrigerator, the total bacterial count and coliform count on the shell surface of the four treatments continued to gradually increase, but the highest counts were recorded in T1 (control)t treatment (control). Concluded that treating table eggs with ultrasound for 1 or 2 min. decreased bacterial count level of table eggs during storage in the refrigerator.

Keywords: Bacterial count, Storage, Table eggs, Ultrasound.

Introduction

Table eggs are good source of protein source for human nutrition, it contains all the essential amino acids needed by the human body, and the percentage of protein retained in the body of protein consumed is equal to 100% (Al-Obaidi and Al-Shadeedi, 2022). also, eggs provide all the essential amino acids, fatty acids and fat-soluble vitamins, a large number of mineral elements, and low energy content, low calories (Abed et al., 2025).

Being egg a low-cost animal protein, and eggs are one of the most consumed foods around the world due to their multifunctional properties such as ease of preparation and delicious taste so, it included in many recipes and food industries for all ages, because it contains All the essential amino acids needed by the

human body. (Obi and Igbokwe, 2007; Al-Obaidi et al., 2019; Sabbah et al., 2024).

In the same time table eggs are perishable food like milk and meat due to their contain a high percentage of moisture, protein and amino acids as an important source for the growth of microorganisms (Al-Shadeed, 2023).

Fresh eggs initially have low microorganism counts. However, contamination and subsequent microbial growth begin rapidly once the egg contacts the environment, particularly within housing facilities and during handling and transport (Sabbah et al., 2024). Also, egg contain three layers of protection; the calcareous shell, inner and outer shell membranes, each of these layers has an important and effective role in protecting the egg content and reducing or

entry and invasion of microorganisms (Morsi et al., 2015; 2023; Salman et al., 2023).

There is no ideal method to store eggs that prevent them from spoilage or corruption, all methods of storing eggs are try to reduce the deterioration of quality characteristics and prolong shelf life. It is necessary that the fresh egg reaches the consumer with high quality using effective new processing techniques. (Dev, et al., 2008; Shenga et al., 2010; Al-Shadeedi, 2018; Oliviera et al., 2022). Deactivating or inactivating microorganisms is one of the most important factors in the use of egg and food preservation technologies (Pelletier et al., 2005). Conventional heat pasteurization is one of the best common technologies currently used to kill and damage microorganisms in food and food products such as eggs. Sterilization technologies are also used for liquid and solid foods, as are drying, freezing, bleaching, and irradiation (Al-Shadeedi and Al-Obaidi, 2025). Heat treatment inactivates or kills microorganisms and some germs, but it is incapable of inactivating or killing thermophilic microorganisms. Killing thermophilic microorganisms during processing requires increased temperature and exposure time, which damages or destroys some food nutrients. The processing time and temperature are directly proportional to the quantity of nutrient loss, induced undesirable flavors, and the deterioration of the functional properties of food and food products (Agriculture.Institute, 2023). Therefore, to replacing traditional heat methods of food preservation, ultrasound has used as a green technology that

destroys pathogenic microorganisms without side effect or damaged beneficial ones, while preserving the organoleptic properties of food and food products (Lauteri et al., 2023). Powerful ultrasound enhances food and food products safety and extending shelf life by reducing spoilage and harmful microorganisms and substances; this action is achieved through the destructive mechanism called cavitation (Ravikumar et al., 2017; Yüceer and Caner, 2020; Nagy et al., 2022; Ozlem and Yilmaz, 2023).

The aim of this study was to determine the effect of treating fresh table eggs for different periods of time (0, 1, 2 and 3) minutes in an ultrasound device as a means of studying its effect on its some bacterial indicators, which included total bacterial count total coliform count after storing it in the refrigerator for (0, 1, 2, 4 and 8) weeks.

Materials and Methods

Ethical approval: The animals of the study were conducted using the guidelines for the care and handling of animal accordance to the Palmtree Environmental and Agricultural Organization Committee (certificate no. 1F1801034, January 25th 2018), this research is a proposal in Poultry Products Technology, College of Veterinary Medicine, University of Baghdad, Baghdad, Iraq.

Egg collection: A total of 240 fresh table eggs (Brown shell eggs) were randomly collected from 20000 Luhman chicken layer flock at Al-Amir project commercial farm, Al-Musaib city, Iraq. The layers were fed a production ration as explain in Table (1).

Table (1): Components and ingredients quantity of ration.

Components	(%)
Corn	15.0
Soya Meal	25.0
Wheat	10.0
Wheat bran	10.0
Rice bit	20.0
Chickpea	10.0
Premix *	2.5
Vegetable oil	1.25
Limestone	6.25
Total	100 Kg
Calculated analysis	
Total protein %	18.75
Metabolic energy Kcal/Kg feed	2650
Lysine (%)	0.77
Methionine (%)	0.30
Methionine + cysteine (%)	0.59
Ca (%)	3.50
P Available (%)	0.35

*Premix supplied diet the following: vitamin A: 12,000 IU; vitamin D3: 2500 IU; vitamin E: 30 IU; vitamin K3: 2 mg; thia- mine: 2.25 mg; riboflavin: 7.5 mg; pyridoxine: 3.5 mg; cobalamine: 0.02 mg; niacin: 45 mg; D-pantothenic acid: 12.5 mg; biotin: 0.125 mg; folic acid: 1.5 mg, zinc: 50; copper: 12; iodine: 0.3; cobalt: 0.2; iron: 100; selenium: 0.1.

Period of the study

This experiment was conducted at the food hygiene laboratory, College of Veterinary Medicine, University of Baghdad, from October 2nd 2024 to February 10th 2025, to compare between four periods of ultrasound treatments of shell table eggs which were 0-, 1-, 2-, and 3-minutes using ultrasound device on bacterial counts during Zero, 1, 2, 4 and 8 weeks of refrigerator storage.

Treatment groups: After egg collection 240 eggs were immediately distributed into four groups of treatments; T1: 60 eggs were untreated eggs as control group. T2: 60 eggs were ultrasound exposed for 1 min. T3: 60 eggs were ultrasound exposed for 2 min.

T4: 60 eggs were ultrasound exposed for 3 min. All eggs were arranged in plastic eggs tray (30 eggs per tray) and refrigerator storage (3-7°C) immediately after treatment.

Storage periods: All eggs were refrigerator storage for 1, 2, 4 and 8 weeks. At each period 12 eggs from each treatment were randomly collected and individually weight and interior quality parameter which included yolk height, yolk diameter, yolk index, white height, yolk weight and percentage, egg components percentage and bacterial counts included total bacterial count and total coliform count were studied.

Ultrasound device: This device is a commercial ultrasonic device and is used to clean food and other delicate items using ultrasonic waves and water solution. This device is of the (GT SONIC) type, Chinese origin.

Bacterial counts: All bacterial count tests were conducted in the laboratory of the Milk Hygiene at the College of Veterinary Medicine, University of Baghdad, and were done on 6 eggs (three replicates) for each treatment and after each storage period. Two eggs of each replicate were immersed with 100 ml of sterile peptone water in polyethylene bags (Accumix company) at sterile conditions and rinsed with accurate for 2 min. then 1ml of the solution was transferred to screw capped bottles containing 9 ml of sterile peptone water to make decimal dilutions of 10 ml each. The culture media used in bacteriological examinations were sterilized at 121 °C for 15 minutes and under a pressure of 15 pounds / square inch. As for the different glassware, they were sterilized using

electric oven at 180°C for three hours (Anburaj, 2020).

Total bacterial count: Total bacterial counts were determined using the pour-plate method, as described by Anburaj (2020). Briefly, 1 mL of each decimal dilution was pipetted into two empty, sterile Petri dishes (duplicates). Approximately 15 mL of sterile Nutrient Agar medium (Accumix company, Zimbabwe). The culture medium and bacterial dilution were thoroughly mixed by gently rotating the plates clockwise and counter-clockwise. Once the agar solidified, the plates were incubated inverted at 37°C for 24 hours. Colonies were counted on plates containing 30 to 300 colonies. The estimated number of bacteria per egg (CFU/mL) was calculated by multiplying the average colony count by the reciprocal of the corresponding dilution factor.

Coliform bacterial count: Coliform bacteria were enumerated using the pour-plate method, as specified by Anburaj (2020). In this procedure, 1 mL of each serial decimal dilution was pipetted into duplicate empty, sterile Petri dishes. Approximately 15 mL of sterile MacConkey Agar medium (Accumix company, Zimbabwe), was immediately added to each dish. The bacterial dilution and culture medium were mixed thoroughly by gently swirling and rotating the plates. Once the agar solidified, the plates were inverted and incubated at 37°C for 24 hours. Colonies were counted on plates containing 30 to 300 colonies. The estimated number of coliform bacteria per egg (CFU/mL) was calculated by multiplying the average colony count by the reciprocal of the corresponding dilution factor.

Statistical analyses: Data were analyzed by using the General Linear Model Procedure of SAS (2001). Means were compared by the Duncan's Multiple Range test at 5% probability.

Results and Discussion

Table (2) shows the effect of ultrasonic treatment on the bacterial counts on the surface of the shell of table eggs during refrigerator storage. T1 recorded the highest total bacterial count and coliform count at Zero-time of storage which were 43×10^2 and 38×10^2 CFU/egg respectively ($p < 0.05$). Whereas, all ultrasound treatments significantly decreased total bacterial count and coliform count, T2 reaching 37×10^1 and 33×10^1 CFU/egg, T3 and T4 reached the A lowest counts (< 100) ($p < 0.05$).

As the storage period extending to 1, 2, 4 and 8 weeks, the significant differences continued, as the first treatment recorded the highest total bacterial count and coliform count, followed by T2, T3 and T4. At 8 weeks of storage, T1 reached 147×10^5 and

187×10^4 CFU/egg, with significant difference from T2 (41×10^4 and 62×10^3 CFU/egg) respectively, T3 (66×10^3 and 126×10^2 CFU/egg) respectively and T4 (93×10^2 and 84×10^2 CFU/egg) respectively ($p < 0.05$).

Table (2): Effect of ultrasound treatments on egg bacterial count during refrigerator storage (cfu/egg).

Ultrasound Treatments	Total count				
	Zero time	1 week	2 weeks	4 weeks	8 weeks
T1	43×10^2 $\pm 18.28^a$	148×10^2 $\pm 30.12^a$	98×10^3 $\pm 33.28^a$	183×10^4 $\pm 43.52^a$	147×10^5 $\pm 36.43^a$
T2	37×10^1 $\pm 20.10^b$	128×10^1 $\pm 26.35^b$	61×10^2 $\pm 31.55^b$	84×10^3 $\pm 38.64^b$	41×10^4 $\pm 35.18^b$
T3	< 100 $\pm 0.00^c$	< 100 $\pm 0.00^c$	72×10^1 $\pm 22.54^c$	97×10^2 $\pm 37.29^c$	66×10^3 $\pm 36.23^c$
T4	< 100 $\pm 0.00^c$	< 100 $\pm 0.00^c$	34×10^1 $\pm 30.15^d$	149×10^1 $\pm 38.03^d$	93×10^2 $\pm 35.19^d$
Significant	*	*	*	*	*

Ultrasound Treatments	Total coliform				
	Zero time	1 week	2 weeks	4 weeks	8 weeks
T1	38×10^2 $\pm 8.41^a$	138×10^2 $\pm 8.38^a$	67×10^3 $\pm 8.91^a$	163×10^3 $\pm 9.65^a$	187×10^4 $\pm 9.51^a$
T2	33×10^1 $\pm 8.54^b$	55×10^1 $\pm 8.41^b$	42×10^2 $\pm 9.03^b$	109×10^2 $\pm 9.54^b$	62×10^3 $\pm 9.64^b$
T3	< 100 $\pm 0.00^c$	< 100 $\pm 0.00^c$	58×10^1 $\pm 8.17^c$	40×10^2 $\pm 9.26^c$	126×10^2 $\pm 9.54^c$
T4	< 100 $\pm 0.00^c$	< 100 $\pm 0.00^c$	34×10^1 $\pm 8.35^d$	148×10^1 $\pm 9.25^d$	84×10^2 $\pm 9.60^d$
Significant	*	*	*	*	*

All data as mean \pm SD, T1: Control, T2: ultrasound for 1 min., T3: ultrasound for 2 min., T4: ultrasound for 3 min., ^{a, b, c} superscripts in a column significantly differ, N.S. not significant, * ($p < 0.05$).

Many studies indicates that ultrasound has a positive and significant effect on food preservation, but few are involved table eggs (Aboonajmi et al., 2010; Aboonajmi et al., 2014). Ultrasound treatments of table eggs for 1, 2, and 3 min. (T2, T3 and T4) have significant ($p < 0.05$) effects to decrease total bacterial count and coliform count of the surface of the eggs compared with T1 (control) as shown in Table (5). These results indicated that ultrasound frequency or ultrasound waves disrupt tissues and molecular structures, causing a cavitation phenomenon (Jose et al., 2014; Ravikumar et al., 2017). These waves, in turn, contributed to the destruction of microorganisms on the surface of the eggshell in the three treatments in which ultrasound was used: T2, T3 and T4 (1, 2, and 3 min. of ultrasound treatment, respectively). The greatest decrease in bacterial counts, represented by total bacterial counts and total coliform counts, occurred immediately after the ultrasound treatment, with bacterial counts reaching less than 100 CFU/egg in T3 and T4, as explained in

Table (5), in the same time T4 (ultrasound for 3 min) may be high destructive to biological structures at this duration (3 min.), this may be what happened in which not gave better internal egg quality characteristics compared with T2 and T3 (Jayasooriya et al., 2007; Ozlem and Yilmaz, 2023). The increased in the count of bacterial count the surface of the eggshell during storage is a natural result of the proliferation and spread of bacteria. However, the highest count occurred in T1 (control treatment), which was untreated and these results agreed with Ismail et al. (2025). Studies indicate that table eggs are completely free of microorganisms the moment they leave the hen's body, but they soon begin to become contaminated through contact with the outer surface of the egg with the external components. The degree of contamination of the egg shell surface depends on several external factors related to field management or egg production halls, including the degree of

cleanliness of the nests (Stadelman et al., 2017; Jones et al., 2018).

The problems of microorganisms on the surface of the egg shell are represented in the penetration of these microorganisms into the egg period and its membranes through the open pores in the egg shell and access to the internal contents of the egg, the first of which is the egg white, and thus the rotting and spoilage of the eggs (Al-Obaidi et al., 2010). Ultrasound is a low-heat treatment able to reduce the count pathogenic bacteria like of *E. coli* from 5-log CFU×ml⁻¹ below 10 CFU×ml⁻¹ in egg products (Nagy et al., 2022).

Conclusions

Application of ultrasound treatment for 1 or 2 min. preserves a good interior quality and components of table eggs. Also, reduces the total bacterial count and coliform counts on the surface of table eggs compared to untreated eggs during refrigerator storage up to 8 weeks. Thus, ultrasound treatment is a good technique for extending the storage shelf life of shelled table eggs and suggestion further studies on treating table eggs during ambient storage and for hatching eggs.

References

- Abed, S.M., Khalid, A. and Al-Shadeedi, Sh.M.J. (2025). Effect of Coating Hatching Eggs with Nanoparticles and Carboxymethyl Cellulose and Storage periods on Hatchability and Quality of Hatched Chicks. *Euphrates Journal of Agricultural Science*, 17 (3): 853-867. Available at: [73390591207964146038434505fff1e6.pdf](https://doi.org/10.3390/91207964146038434505fff1e6.pdf)
- Aboonajmi, M., Akram, A., Nishizu, T., Kondo, N., Setarehdan, S.K. and Rajabipour, A. (2010). An ultrasound-based technique for the determination of poultry egg quality. *Research in Agricultural Engineering*, 56(1): 26–32. Available at: [An ultrasound based technique for the determination of poultry egg quality](https://doi.org/10.1080/10942912.2013.770015)
- Aboonajmi, M., Setarehdan, S.K., Akram, A., Nishizu, T. and Kondo, N. (2014). Prediction of Poultry Egg Freshness Using Ultrasound. *International Journal of Food Properties*, 17:1889–1899. Available at: <http://dx.doi.org/10.1080/10942912.2013.770015>
- Agriculture.Institute (2023). Effective Methods to Control Microorganisms in Food. *Food Microbiology* (FV). <https://agriculture.institute/food-microbiology-fv/effective-methods-control-microorganisms-food/>
- Al-Obaidi, F.A. (2010). Using water vapor treatment for reducing deterioration in chemical and functional properties of table eggs during storage. *Tikrit Journal of Agricultural Science*, 10(2): 143-155. Available at: [USING WATER VAPOR TREATMENT FOR REDUCING DETERIORATION IN CHEMICAL AND FUNCTIONAL PROPERTIES OF TABLE EGGS DURING STORAGE | مركز المعرفة الرقمي](https://doi.org/10.3390/91207964146038434505fff1e6.pdf)
- Al-Obaidi, F.A. and Al-Shadeedi, Sh.M.J. (2022). *Egg Science and Chemistry*. 1st ed., LAP LAMBERT Publishing Company, ISBN: 978-620-5-49260-4.
- Al-Shadeedi, Sh.M.J. and Rashad, F.H. (2017). Effect of supplementing two types of food flavor in diet on egg quality and sensory evaluation of Japanese quail. *Euphrates J. Agric. Sci.*, 9(4): 752-761. Available at: [Euphrates Journal of Agricultural Science - Volume 9, Issue 4](https://doi.org/10.3390/91207964146038434505fff1e6.pdf) ملحق الاول
- Al-Shadeedi, Sh.M.J. (2018). Study the microbial contamination of table egg containers and packages in Baghdad. 10th International Poultry Conference – Proceeding, 26 – 29 November 2018, Sharm Elsheikh – Egypt. Available at: [PDF STUDY THE MICROBIAL CONTAMINATION OF TABLE EGG CONTAINERS AND PACKAGES IN BAGHDAD](https://doi.org/10.3390/91207964146038434505fff1e6.pdf)
- Al-Shadeedi, Sh.M.J. (2023). Designer egg a new and valuable items of table egg. *Journal of Modern and Heritage Science*, 12(1):87-100. Available at: [PDF Designer egg a new and valuable table egg](https://doi.org/10.3390/91207964146038434505fff1e6.pdf)
- Al-Shadeedi, Sh.M.J. and Al-Obaidi, F.A. (2025). *Poultry and Eggs Inspection and Preservation*. 1st ed., LAP LAMBERT Academic Publishing, ISBN: 978-620-8-45543-9.
- Anburaj, R. (2020). *Text Book on Food Microbiology*. 1st ed., Publisher: Ryan publishers, Editor: P.F. Steffi, ISBN: 978-81-947191-6-8. ISBN: 978-81-947191-6-8, 978-81-947191-7-5.
- Dev, S.R.S., Raghavan, G.S.V. and Garipey, Y. (2008). Dielectric properties of egg components and microwave heating for in-shell pasteurization of eggs. *Journal of Food Engineering* 86: 207–214. Available at: <https://doi.org/10.1016/j.jfoodeng.2007.09.027>
- Ismail, T.H., Atiyah, T.T. and Al-Shadeedi, Sh.M.J. (2025). Effect of microwave pasteurization on bacterial quality of table eggs during refrigerator storage. *Alnakhla J. Sci.*, 4(1):1-6. Available at: <https://doi.org/10.63799/jk0c6x70>
- Jayasooriya, S.D., Bhandari, B.R., Torley, P., D'Arcy, B.R. (2007). Effect of high-power ultrasound

- waves on properties of meat: A Review. *International Journal of Food Properties*, 10: 911–922. Available at: <https://doi.org/10.1081/JFP-120030039>
- Jones, D.R., Ward, G.E., Regmi, P. and Karcher, D.M. (2018). Impact of egg handling and conditions during extended storage on egg quality. *Poult. Sci.* 97, 716–723. Available at: <https://doi.org/10.3382/ps/pex351>
- Jose, D.S., Andrade, D., Ramos, N., Vanetti, A.M. and Chaves, J.B. (2014). Decontamination by ultrasound application in fresh fruits and vegetables. *Food Control*. 45: 36-50. Available at: <http://dx.doi.org/10.1016/j.foodcont.2014.04.015>
- Lauteri, C., Ferri, G., Piccinini, A., Pennisi, L. and Vergara, A. (2023). Ultrasound Technology as Inactivation Method for Foodborne Pathogens: A Review. *Foods*, 12(6): 1212. Available at: <https://doi.org/10.3390/foods12061212>
- Morsy, M.K., Sharoba, A.M., Khalaf, H.H., El-Tanahy, H.H. and Cutter, C.N. (2015). Efficacy of antimicrobial pollutant-based coating to improve internal quality and shelf-life of chicken eggs during storage. *J. Food Sci.* 80, M1066–M1074. Available at: <https://doi.org/10.1111/1750-3841.12855>
- Nagy, D., Baranyai, L., Nguyen, L.L., Brückner, A.T., Zsom, T., Németh, C., Felföldi, J. and Zsom-Muha, V. (2022). Combined Effect of Ultrasound and Low-Heat Treatments on *E. coli* in Liquid Egg Products and Analysis of the Inducted Structural Alterations by NIR Spectroscopy. *Sensors*, 22(24): 9941. Available at: <https://doi.org/10.3390/s22249941>
- Obi, C.N. and Igbokwe, A.J. (2007). Microbiological analysis of freshly laid and stored domestic poultry egg in selected poultry farms in Umuahia, Abia State, Nigeria. *Res. J. Biol. Sci.*, 4(12): 1297-1303. Available at: <http://dx.doi.org/10.3923/rjbsci.2009.1297.1303>
- Ozlem, V.A. and Yilmaz, E. (2023). Effects of ultraviolet and ultrasound treatments applied before the storage period on egg quality characteristics. *Int. J. Agric. Environ. Food Sci.*, 7(1): 206-212. Available at: <https://doi.org/10.31015/jaefs.2023.1.25>
- Pelletier, J.P.R., Transue, S. and Snyder, E.L. (2005). Pathogen inactivation techniques. *Best Pract Res Clin Haematol.*, 19(1):205–242. Available at: doi: [10.1016/j.beha.2005.04.001](https://doi.org/10.1016/j.beha.2005.04.001)
- Ravikumar, M., Suthar, H., Desai, C. and Sachin, A.J. (2017). Ultrasonication: An Advanced Technology for Food Preservation. *Int. J. Pure App. Biosci.*, 5 (6): 363-371. Available at: <http://dx.doi.org/10.18782/2320-7051.5481>
- Salman, K.Q., Mohammed, R.M. and Al-Shadeedi, Sh.M.J. (2023) Effect of some natural coating of table egg on shelf life during refrigerator storage. *Journal of Genetic and Environmental Resources Conservation*, 11(2):103-113. Available at: <https://ojs.gercj.com/index.php/gercj/article/view/229>
- SAS Institute, (2001). *SAS/STAT User's Guide for Personal Computer*. Release 6.12 SAS Institute, INC., Cary, N.C., USA.
- Sabbah, M., Badrasawi, K., Kharraz, L. and Badrasawi, M. (2024). Knowledge and handling practices for raw hen's eggs during purchase, preparation, storage, and consumption: a cross-sectional study. *Scientific Reports*, 14(1): 7122. Available at: <https://doi.org/10.1038/s41598-024-56288-8>
- Shenga, E., Singh, R.P. and Yadav, A.S. (2010): Effect of pasteurization of shell egg on its quality characteristics under ambient storage. *J. Food Sci. Technol.*, 47(4): 420–425. Available at: <https://doi.org/10.1007/s13197-010-0069-2>
- Stadelman, W.J. and Cotterill, O.J. (1995). *Egg Science and Technology*. 4th ed., Food products press. An Imprint of the Haworth Press. INC. New York. London.
- Yuceer, M. and Caner, C. (2020). The effects of ozone, ultrasound and coating with shellac and lysozyme–chitosan on fresh egg during storage at ambient temperature. Part II: microbial quality, eggshell breaking strength and FT-NIR spectral analysis. *International Journal of Food Science and Technology*, 55, 1629–1636. Available at: <https://doi.org/10.1111/ijfs.14422>